EGU25-1650, updated on 23 Apr 2026
https://doi.org/10.5194/egusphere-egu25-1650
EGU General Assembly 2025

DiffScale: Towards Continuous Downscaling and Bias Correction in Subseasonal Wind Speed Forecasts

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Renewable resources are strongly dependent on local and large-scale weather situations. Skillful subseasonal to seasonal (S2S) forecasts -beyond two weeks and up to two months- can offer significant socioeconomic advantages to the energy sector. In particular, accurate wind speed forecasts result in optimized generation of wind-based electric power. This study aims to enhance wind speed predictions using a diffusion model with classifier-free guidance to downscale S2S forecasts of surface wind speed. We propose DiffScale, a diffusion model that super-resolves spatial information for continuous downscaling factors and lead times. Leveraging weather priors as guidance for the generative process of diffusion models, we adopt the perspective of conditional probabilities on sampling super-resolved S2S forecasts. We aim to directly estimate the density, associated with the target S2S forecasts at different spatial resolutions and lead times without auto-regression or sequence prediction, resulting in an efficient and flexible model. Synthetic experiments were designed to super-resolve wind speed S2S forecasts from the European Center for Medium-Range Weather Forecast (ECMWF) from a coarse resolution to a finer resolution of data from ERA5, which serves as a high-resolution target, derived from reanalysis data. We achieve a significant increase in the quality of predictions, utilizing the proposed diffusion model for continuous downscaling and bias correction of the ECMWF forecasts.